SECTION 12—MARINE SYSTEMS TECHNOLOGY

OVERVIEW

This section covers several technology areas. These technology areas include technology items that are militarily critical. **Propulsors and Propulsion Systems** include technologies that enhance the range, endurance, and survivability of surface and subsurface vessels by improving propulsive efficiency and quietness. **Signature Control** for marine applications involves technologies, materials, and equipment related to development, testing, and production of surface and subsurface vessels with reduced acoustic, infrared, radar, magnetic, and visual signatures (signature control for broader applications is covered in Section 16); **Survivability** involves technologies to reduce vulnerability to adversary weapons and to improve damage control. **Subsurface and Deep Submergence Vessels** include technologies and hardware related to manned and unmanned, tethered and untethered submersible vehicles; underwater vision systems; and undersea robots and manipulators. Most critical technology items with marine applications in **Guidance, Navigation, and Control** and in **Sensors** are covered in Sections 7 and 15, respectively. Because of their importance in the operation of submersible vehicles, some technologies related to underwater vision systems and underwater navigation are covered here. No technology items in the following Marine Systems technology areas are currently militarily critical: **Advanced Hull Forms**, **Human Systems Interfaces**, **Ocean Salvage and Deep Sea Implant**, and **Systems Integration**. The principal countermeasure against the mine threat is the unmanned underwater vehicle (UUV), whose technologies are covered under **Subsurface and Deep Sea Vessels**. Technology, material, and equipment for developing, producing, and using undersea mines are covered in Section 2. No other technology items are included under **Undersea Weapon Systems**. Technology related to marine gas turbine engines (GTE), which are derivatives of aero GTE, is covered in Section 1.

SECTION 12.1—PROPULSORS AND PROPULSION SYSTEMS

OVERVIEW

Marine propulsion systems include power plants, which provide power to propel vehicles, and propulsors, which convert power to thrust. Power plants include marine gas turbines, which are discussed in MCTL 1.2 with technologies for air and ground gas turbine engines, and air independent power (AIP) systems, which include thermal engines and electrochemical power sources. The AIP systems include closed-cycle or semi-closed-cycle thermal engines that produce electrical or mechanical power from stored energy sources independent of the atmosphere. Four types of AIP thermal engines are candidates to power submarines and other underwater vehicles: (1) the closed-cycle Brayton or GTE, (2) the closed-cycle Rankine or steam turbine; (3) the closed-cycle Stirling piston engine; and (4) the semi-closed-cycle diesel engine. AIP systems also include electrochemical power sources, i.e., fuel cells, nonrechargeable batteries, rechargeable batteries, and thermoelectric devices. Propulsors include propellers, pumpjets and waterjets. There are several screw-type propellers, which are distinguished by their abilities to accommodate the effects of cavitation, which generates noise and reduces propeller efficiency. The waterjet is a different type of propulsor. As an alternative for countering propeller cavitation problems for high-speed craft and special-purpose craft, the waterjet, which is driven by a gas turbine or high speed diesel, provide a jet-reactive thrust of high-velocity water expelled through a nozzle. With a speed range above 45 knots, waterjets, whose principal advantage is improvement of vehicle maneuverability, are typically applied to patrol boats, surface effect ships, hydrofoils, motor yachts, and fast ferries.

Table 12.1-1. Propulsors and Propulsion Systems Militarily Critical Technology Parameters

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
Software for repair, overhaul, or refurbishing (rematching) of specially designed propellers; Tolerance of blade radius	Tolerance + 0 to –1% of design	None identified	CAD/CAM controlled milling machines	To achieve required tolerance	WA IL Cat 8 WA ML 9
Software for repair, overhaul, or refurbishing (rematching) of specially designed propellers: Pitch tolerance	Tolerance ± 2 % of design at any section ± 1 and 1/2% average for each blade	None identified	CAD/CAM controlled milling machines	To achieve required tolerance	WA IL Cat 8 WA ML 9
Software for repair, overhaul, or refurbishing (rematching) of specially designed propellers: Tolerance of blade section width	Tolerance + 1% to – 5% of design at each blade radius	None identified	CAD/CAM controlled milling machines	To achieve required tolerance	WA IL Cat 8 WA ML 9
Software for repair, overhaul, or refurbishing (rematching) of specially designed propellers: Thickness tolerance	Tolerance + 2% to – 5% of maximum design thickness or –1/16 inch, whichever is greater at each design radius	None identified	CAD/CAM controlled milling machines	To achieve required tolerance	WA IL Cat 8

(Continued)

Table 12.1-1. Propulsors and Propulsion Systems Militarily Critical Technology Parameters (Continued)

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
Software for repair, overhaul, or refurbishing (rematching) of specially designed propellers: Track tolerance at 0.95R	Tolerance is 1/2% of propeller design radius	None identified	CAD/CAM controlled milling machines	To achieve required tolerance	WA IL Cat 8
Software for repair, overhaul, or refurbishing (rematching) of specially designed propellers: Clearance tolerance	Cylindrical: 1/32 inch Edge gage: 1/64 inch or surface being checked Fairing rod: 1/32 inch	None identified	CAD/CAM controlled milling machines	To achieve required tolerance	WA IL Cat 8
Software for repair, overhaul, or refurbishing (rematching) of specially designed propellers: Tolerance for special surface porosity limits	1/64 inch maximum dimension in l-inch wide band, each face, along leading edge, and at break of knuckle along trailing edge	None identified	CAD/CAM controlled milling machines	To achieve required tolerance	WA IL Cat 8
Software for repair, overhaul, or refurbishing (rematching) of specially designed propellers: Surface finish tolerance	Blades: 63 rms micro-inch Hub: 125 rms micro-inch	None identified	CAD/CAM controlled milling machines	To achieve required tolerance	WA IL Cat 8
Water-screw propeller or power transmission systems for ACV, SES hydrofoil and SWAS vessels-Super-cavitating, super-ventilated, partially-submerged, or surface piercing propellers	Power rating > 7.5 MW and speeds > 50 knots	None identified	None identified	None identified	WA IL Cat 8 WA ML 9
Water-screw propeller or power transmission systems for ACV, SES hydrofoil and SWAS vessels-Lightweight, high capacity propulsion reduction gearing	K factor > 300	Maraging steel	None identified	None identified	WA IL Cat 8

(Continued)

Table 12.1-1. Propulsors and Propulsion Systems Militarily Critical Technology Parameters (Continued)

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
WATER-SCREW PROPELLER, POWER GENERATION OR TRANSMISSION SYSTEMS FOR USE ON MARINE VESSELS-INTERNALLY LIQUID-COOLED ELECTRIC PROPULSION MOTORS	Output power > 2.5 MW	None identified	Water tunnels with background noise < 100 dB (ref 1 mPa, 1 Hz) in 0–500 Hz frequency band	None identified	WA IL Cat 8
WATER-SCREW PROPELLER, POWER GENERATION OR TRANSMISSION SYSTEMS FOR USE ON MARINE VESSELS-SUPERCONDUCTIVE OR PERMANENT MAGNET ELECTRIC PROPULSION ENGINES	Output power > 0.1 MW	None identified	Water tunnels with background noise < 100 dB (ref 1 mPa, 1 Hz) in 0–500 Hz frequency band	None identified	WA IL Cat 8
WATER-SCREW PROPELLER, POWER GENERATION OR TRANSMISSION SYSTEMS FOR USE ON MARINE VESSELS-COMPOSITE SHAFT SYSTEMS	Transmission capability > 1.0 MW	None identified	None identified	None identified	WA IL Cat 8
WATER-SCREW PROPELLER, POWER GENERATION OR TRANSMISSION SYSTEMS FOR USE ON MARINE VESSELS-VENTILATED AND BASE-VENTILATED PROPELLER SYSTEMS	Power rating > 2.5 MW	None identified	None identified	None identified	WA IL Cat 8
WATER-SCREW PROPELLER, POWER GENERATION OR TRANSMISSION SYSTEMS FOR USE ON MARINE VESSELS-QUIET MARINE PROPULSORS	Thrust loading coefficient < 0.5 and power rating > 500 shaft HP	None identified	None identified	None identified	WA IL Cat 8
PUMPJET PROPULSION SYSTEMS UTILIZING DIVERGENT NOZZLE AND FLOW CONDITIONING VANE TECHNIQUES	Output > 2.5 MW	None identified	Water tunnels with background noise < 100 dB (ref 1 mPa, 1 Hz) in 0–500 Hz frequency band	None identified	WA IL Cat 8
MODELS AND CODES THAT DEFINE HYDRODYNAMIC FLOW - AROUND PROPULSORS	10^9 computer floating point operations	None identified	None identified	None identified	None

(Continued)

Table 12.1-1. Propulsors and Propulsion Systems Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
MODELS AND CODES THAT DEFINE HYDRODYNAMIC FLOW - INVISCOUS FLOW AROUND VESSELS	10^{11} computer floating point operations	None identified	None identified	None identified	None
MODELS AND CODES THAT DEFINE HYDRODYNAMIC FLOW - VISCOUS FLOW AROUND VESSELS	10^{11} computer floating point operations	None identified	None identified	None identified	None
VARIABLE PRESSURE WATER TUNNEL FOR MEASURING CAVITATION AND ACOUSTIC FIELDS UNDERWATER	Background noise < 100 dB (reference 1 μPa, 1 Hz); Frequency Range 0–500 Hz; Tunnel speed up to 18 m/sec; Pressure range 0.2 to 60 psia	None identified	None identified	None identified	WA IL Cat 8

SECTION 12.2—MARINE SIGNATURE CONTROL AND SURVIVABILITY

OVERVIEW

This subsection covers several categories of signature reduction. **Acoustic:** Surface ships and submarines emit high levels of underwater noise that can be detected and tracked by passive sonars. The noise can also interfere with a vessel's own sonar, thereby reducing its own effectiveness. **Infrared:** Controlling IR signatures involves controlling the temperature and emissivity of a ship's exposed surfaces. Hot spots (for example, an exhaust stack) are easier to detect than warm targets (for example, a ship's hull), so hot parts are cooled or screened from direct view of IR-homing missiles. **Radar:** Reducing radar detectability involves: (1) using structural material that is an absorber; (2) covering the target object with radar absorbing material (RAM); and (3) shaping the target so it scatters the incident energy rather than reflecting this energy back in the source direction (which a specular reflector does). **Wake:** As a ship moves along the sea surface, it generates surface and underwater wakes that can be detected by various sensor systems: visual, conventional, and IR photography; IR radiometry; and microwave radiometry. **Magnetic:** Vessels can be treated to reduce magnetic signatures by either or a combination of two countermeasure techniques: deperming and degaussing. **Visual:** The visible part of the electromagnetic spectrum is not susceptible to reduction of echoing area techniques. Camouflage, light, smoke screen, and cloud cover are about the only ways to impede detailed target recognition. Survivability technologies include means to reduce vulnerability and to improve damage control. Refer to Section 16 for additional treatment of signature control.

Table 12.2-1. Marine Signature Control and Survivability Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
ACOUSTIC SIGNATURE: PASSIVE MOUNTS FOR ACOUSTIC ISOLATION AND OTHER COMPONENTS FOR VIBRATION ISOLATION BY ACOUSTIC MOUNTS WITH INTERMEDIATE MASS < 30% OF EQUIPMENT MASS TO BE MOUNTED.	Frequency 10 Hz–100 kHz Isolation performance > 6 dB	None identified	Vessel noise measurement systems	None identified	WA IL Cat 8
ACOUSTIC SIGNATURE: ACTIVE NOISE REDUCTION OR CANCELLATION SYSTEMS, OR MAGNETIC BEARINGS AND ELECTRONIC CONTROLS FOR SUCH SYSTEMS	Noise reduction > 6 dB for systems with > one degree of freedom	None identified	Vessel noise measurement systems	Active control software	WA IL Cat 8
NOISE REDUCTION TECHNIQUES FOR PROPULSION AND AUXILIARY MACHINERY	Attenuation > 6 dB	None identified	Vessel noise measurement systems. Materials characterization measurement systems	None identified	WA IL Cat 8

(Continued)

Table 12.2-1. Marine Signature Control and Survivability Militarily Critical Technology Parameters (Continued)

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
Acoustic Signature: Coatings and materials for acoustic signature control	Frequency < 10 Hz–100 kHz Noise reduction > 6 dB	None identified	Vessel noise measurement systems. Materials characterization measurement systems	None identified	WA ML 9
Acoustic Signature: Models to predict acoustic signature of a surface or subsurface vessel in the ocean environment	Empirical validation causing any (> 0) change(s) to model algorithms based solely on theory	None identified	None identified	Empirical validation causing any (> 0) change(s) to model algorithms based solely on theory	WA ML 9
IR Signature 0.7–20 μm: Engine exhaust signature suppression system for diesel or gas turbine systems	> 50% reduction of IR signature	None identified	Vessel IR measurement systems. Materials characterization measurement systems	None identified	WA ML 9
IR Signature 0.7–20 μm: Active or passive systems to reduce or control IR signature of ship structure	> 50% reduction of IR signature	None identified	Vessel IR measurement systems. Materials characterization measurement systems	None identified	WA ML 9
IR Signature 0.7–20 μm: Materials, coatings, appliques, and paints to reduce or control IR signature	Reflectivity ≥ 0.8 or ≤ 0.2 and RF transparent	Shipboard-suitable material with critical parameter characteristics	Vessel IR measurement systems. Materials characterization measurement systems	None identified	WA ML 9
IR Signature: Models to predict IR or EO signature of a surface ship or submarine in the ocean environment	Empirical validation causing any (> 0) change(s) to model algorithms based solely on theory	None identified	None identified	Validated signature algorithms	None
RF Signature: 1 MHz–1,000 GHz: Physical models for measuring radar signatures at millimeter and submillimeter wavelengths	Non-metallic scale models whose performance is < 3 dB different than full-scale models	Model materials with scaled dielectric characteristics	Materials characterization measurement systems	None identified	WA ML 9
RF Signature: 1 MHz–1,000 GHz: Radar absorbing structure with frequency selective or circuit analog materials	Absorption ≥ 15 dB; bandwidth > 15% of center frequency; thickness ≤ 1/2 wavelength; area > 1 m^2; density < 4 g/cm^3	Composites with conductive circuit composites	Materials characterization measurement systems	None identified	WA ML 9

(Continued)

Table 12.2-1. Marine Signature Control and Survivability Militarily Critical Technology Parameters (Continued)

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
RF signature: 1 MHz–1,000 GHz: Windows treated for radar signature reduction	< 50 ohms/square with > 50% transparency	Dielectrics, plastics, and glass	Materials characterization measurement systems	None identified	WA ML 9
RF signature: 1 MHz–1000 GHz: Magnetic and electric absorbing materials	Absorption ≥ 15 dB; band width > vice ≥ 15% of center frequency; thickness ≤ 1/2 wavelength; area > 1 m^2; density < 4 g/cm^3	Composites with magnetically and electrically loaded components	Materials characterization measurement systems	None identified	WA ML 9
RF signature: 1 MHz–1,000 GHz: Intrinsically conductive polymeric materials	< 50 ohms/square	Conductive polymers	Materials characterization measurement systems	None identified	WA ML 9
RF signature: 1 MHz–1,000 GHz: Graded resistive films	< 25 ohms/square	Dielectrics and plastics with variable resistivity	Materials characterization measurement systems	None identified	WA ML 9
RF signature: 1 MHz–1,000 GHz Blast-resistant or high-wear area RAM	> 10 dB absorption and suitable for missile blast zone or high abrasion application	Composites and ceramics	Materials characterization measurement systems	None identified	WA ML 9
RF signature: 1 MHz–1,000 GHz: Integrated aperture or conformal aperture antenna	> 50 % reduction in RCS	None identified	RF and RCS measurement ranges	None identified	WA ML 9
RF signature: 1 MHz–1,000 GHz: Loaded foam, loaded cores and fiber-loaded planar or variable graded absorbers	Strength > 100 psi in tension and compression; > 60 psi shear strength	Structural composites	Materials characterization measurement systems	None identified	WA ML 9
RF signature: Databases, design rules, procedures, computer codes, or handbooks concerned with shaping or materials for low-observable (LO) use	Empirical validation is the basis for any (> 0) data in the software	None identified	None	Empirical validation is the basis for any (> 0) data in the software	WA IL Cat. 8
Magnetic signature: Active systems to reduce or control magnetic signature	> 50% reduction in magnetic signature	None identified	Magnetic field strength measurement systems	Use experimentally verified data	WA ML 9

(Continued)

Table 12.2-1. Marine Signature Control and Survivability Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
MAGNETIC SIGNATURE: PASSIVE SYSTEMS TO REDUCE OR CONTROL MAGNETIC SIGNATURE	> 50% reduction in magnetic signature	None identified	Magnetic field strength measurement systems	Use experimentally verified data	WA ML 9
VISUAL SIGNATURE: 0.4 μM–0.7 μM: WINDOWS	Control glint and glare with transparency > 50%	Glass and plastic	Materials characterization measurement systems	None identified	None
VISUAL SIGNATURE: 0.4 μM–0.7 μM: ACTIVE OR PASSIVE SURFACE TREATMENT FOR VISUAL SPECTRUM	Visual signature reduction > 50%; RF and IR compatible	None identified	Materials characterization measurement systems	None identified	WA ML 9
VISUAL SIGNATURE: 0.4 μM–0.7 μM: LOW EMISSIVITY MATERIALS	Emissivity ≤ 0.1	Paints, coatings, appliques	Materials characterization measurement systems	None identified	WA ML 17
LASER SIGNATURE: 0.3 μM–10.6 μM: SURFACE TREATMENTS	Reflectivity < 5%	Paints, coatings, or appliques and materials whose inherent surface characteristics achieve critical parameter performance	Materials characterization measurement systems	None identified	None
MULTISPECTRAL SIGNATURE: MATERIALS WITH MULTISPECTRAL LO QUALITIES	Useful for LO applications in ≥ 2 spectral ranges (RF, IR, EO, magnetic, acoustic)	None identified	Materials characterization measurement systems	None identified	None
MULTISPECTRAL SIGNATURE: MODELS TO PREDICT MULTISPECTRAL SIGNATURE	Multispectral model that covers ≥ 2 bands (UV, visible, NIR, MIR, FIR, RF, magnetic and acoustic) and whose theory-based algorithms have any change (> 0) incorporated as a result of empirical validation	None identified	Materials characterization measurement systems	Validated model algorithms	None

SECTION 12.3—SUBSURFACE AND DEEP SUBMERGENCE VEHICLES

OVERVIEW

This subsection covers technologies associated with the development, production, and operation of submersible vehicles and two groups of equipment that the vehicles use to perform military and nonmilitary tasks. The equipment groups are (1) underwater vision systems and (2) undersea robots and manipulators. The vehicles of principal concern are tethered, unmanned vehicles, called ROVs and untethered, unmanned vehicles called AUVs. Unmanned vehicles, including the tethered ROVs and the untethered AUVs, are identified as UUVs by the Navy. A range of UUVs, whose basic sensor and video systems are a high-resolution sonar and a low-light-level television, respectively, has evolved from the early use of manned submersibles and divers for the offshore oil and gas industry. To work underwater, the submersible platform needs the ability to navigate, to detect and visualize, and, for many tasks, to manipulate tools and/or a target object. Without one ability, the others are not useful. A degradation in one technology area, however, may be partially compensated by an increased capability in another. Searching for small objects, particularly if they are nonmetallic, in a cluttered environment requires the use of vision systems. Detection at long range enables submersible vehicles to acquire a target quickly and, thus, reduces search time. Undersea robots can be used in place of divers and manned submersibles to accomplish underwater work, which might include visual inspection, nondestructive testing, surveying, measuring, welding, and trenching. Remotely controlled articulated manipulators are a type of robotic arm attached to manned or unmanned submersible devices. They are anthropomorphic devices that perform underwater physical work including manipulation and intervention.

Table 12.3-1. Subsurface and Deep Submergence Vehicles Militarily Critical Technology Parameters

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
UNMANNED, UNTETHERED SUBMERSIBLE VEHICLES: STORED ENERGY	Energy density > 150 Whr/kg Life cycle (recharges) > 20 Power density > 15 hp/ft^3	None identified	Test cells	None identified	None
UNMANNED, UNTETHERED SUBMERSIBLE VEHICLES: SUBMERGED LAUNCH AND RECOVERY	Launch and recovery speed (time) 1–3 minutes Low speed control: 1 to 3 knots	None identified	None identified	Control/navigation software	None
UNMANNED, UNTETHERED SUBMERSIBLE VEHICLES: NAVIGATION RELATIVE TO ANY GEOGRAPHICAL REFERENCE	Navigation error rate within 0.2% distance traveled or < 100 m CEP whichever is less	None identified	None identified	System integration/control	WA IL Cat 8
UNDERWATER DATA TRANSMISSION BY FIBER OPTIC CABLE	Data rate > = 1 Gbits/sec Range > = 30 km	None identified	None identified	None identified	WA IL Cat 5
UNDERWATER DATA TRANSMISSION BY ACOUSTIC	Date rate > 20 kbits/sec Range > 4 nmi	None identified	None identified	None identified	None

(Continued)

Table 12.3-1. Subsurface and Deep Submergence Vehicles Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
UNDERWATER VISION SYSTEMS: TV SYSTEMS (CAMERA, LIGHTS, MONITORING AND SIGNAL TRANSMISSION EQUIPMENT) SPECIALLY DESIGNED FOR OPERATION FROM A SUBMERSIBLE VEHICLE	System resolution > 800 lines measured in air; camera resolution > 1100 lines measured in air	None identified	None identified	None identified	WA IL Cat 8 WA ML 9
UNDERWATER VISION SYSTEMS: VISION SYSTEM LENS OPERATION	Standoff ≥ 5 L, where the attenuation length L is the distance at which an optical signal is attenuated by 1/e, where e is the base of the system of natural logarithms	None identified	None identified	None identified	WA IL Cat 8
UNDERWATER VISION SYSTEMS: LLLTV CAMERA FOCAL PLANE ARRAYS	> 150,000 active pixels per solid state area array	None identified	None identified	None identified	WA IL Cat 8
UNDERWATER VISION SYSTEMS: UNDERWATER STILL CAMERAS WITH FILM FORMAT > 35 MM	Operating depth > 1000 m	None identified	None identified	None identified	WA IL Cat 8
STROBOSCOPIC LIGHT SYSTEMS	Output energy > 300 J per flash Flash rate > 5 per sec	None identified	None identified	None identified	WA IL Cat 8
ARGON ARC LIGHT SYSTEMS	Usable at depths > 1000 m	None identified	None identified	None identified	WA IL Cat 8